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AUTHOR Gregg, Lee W.; Farnham-Diggory, Sylvia
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ABSTRACT

A framework for a comprehensive theory of reading is presented in this paper. The framework consists of perceptual, semantic, and control systems. The perceptual and semantic spaces of the theory should not be confused with the terms "decoding" and "comprehension"; decoding and comprehension refer to ways in which those spaces are utilized, requiring specific task demands and stages of practice within those spaces. The third part of the human information processing system is the collection of basic operations and learned programs for performing reading tasks in the other two spaces; in effect, this control system is like a computer program, directing attention to and providing directions for performing a perceptual or semantic reading task. A discussion of each system within the theory, including relevant research, concludes with a taxonomy of reading tasks and the implications of the whole theory for reading research. Discussion following presentation of the paper is included. (RL)

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How to Study Reading: An Information Processing Analysis

Lee W. Gregg

Carnegie-Mellon University

Department of Psychology

Sylvia Farnham-Diggory

University of Delaware

Willard Hall Education Building

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How to Study Reading: An Information Processing Analysis

Lee W. Gregg and S. Farnham-Diggory

We have read in several places lately that the time is not yet ripe for a comprehensive reading model. For example,

> "It is indeed a question whether looking for a model is a worthwhile enterprise. A model implies a paradigm, or a pattern to be closely followed. That any one model will suffice to typify the reading process is doubtful... (Gibson & Levin, 1975)."

And Venezky, in a 1975 NIE report, said:

> "The absence here of any discussion of the complete model for the reading process published in the last 10 years is intentional. After intensive analysis of such models [e.g., those found in the Davis (1971) collation] we believe that we know too little about the component processes to justify attention to complete models (Venezky, 1975).

Why, then, in the face of this collective wisdom, are we about to discuss a comprehensive reading model? There are two major reasons.

First of all, it is not true that we lack comprehensive models of reading. We have dozens of them, hundreds. Everyone has a theory of reading. But in

whole or in part they are implicit theories most of them formulated at a verbal descriptive level. If it has been possible, as Venezky suggests, to identify components of the reading process, e.g. decoding and comprehension, and to study them experimentally, then a model which defines the component boundaries must have existed. For example, an implicit comprehensive theory of reading must have led the NIE study group on models to propose that word recognition is necessary to reading. The problem is not to invent a model. The problem is to make public and testable the consequences of the models we already have.

A second major reason for attempting to build an overall theory of reading is that such a theory is mainly what we lack. Reading involves only a few types of processes and information structures. They are not really a mystery. What is uncertain is how these components go together at high speed. We need ways of characterizing the conditions under which certain processes are evoked. We need the decision rules which fire one cognitive function rather than another. We need to specify characteristics that determine which process gets activated initially, and which produces the final output. Without an explicit model of these control factors, we have no place to put the piecemeal data that our reading laboratories have turned up.

In this paper, then, I will offer a framework for a comprehensive theory of reading.

Insert Figure 1 about here

Fig. 1 is a schematization of the human information processing system. There are three major parts to it. First, we will discuss the <u>perceptual system</u>, the discrimination nets or P-space. We will talk about the outcome of perceptual processing--the act of recognition. Those acts are signified

here by terminal nodes labeled I. Second, we will talk about the semantic system, or S-space.

Note, we have not referred to a decoding system or a comprehension system. The P-space is not a decoding space, nor is the S-space equivalent to comprehension. Decoding and comprehension refer to ways in which both these spaces are utilized. One reason there is much confusion about the terms decoding and comprehension is that we have not been sufficiently careful to specify task demands and stage of practice.

The third part of the human information processing system, then, is the collection of basic operations and learned programs for performing reading tasks. A great deal of confusion arises from differences among reading tasks. To demonstrate how perceptual processes and semantic processes--as diagrammed here--operate during reading, it is necessary to be very specific about the type of reading task referred to. For that reason, we have developed a taxonomy of reading tasks. We will return to an analysis of these tasks following an overview of the structure common to all of them.

The Perceptual Space

Earlier in the history of psychology, as well as in the history of reading instruction, perception was considered a wholistic process, something which happened all-of-a-piece. Over the past two decades, however, we have learned this is not the case. The discoveries have been partly a matter of experimental design, and partly a matter of apparatus development. It is now an accepted fact that perception is a process of noticing a series of features sequentially. We do not perceive the letter E all at once. We perceive a set of horizontal and vertical lines, one at a time. Or possibly,

with practice, we perceive a single higher-order feature--a pattern of horizontal and vertical lines.

We refer to this noticing process as feature-testing. That means, in effect, that such questions are asked as: does the letter have a vertical line in it? Is the letter closed at the top? The tests are being made at high speed, in a few hundredths of a second. With regard to the English alphabet (and thanks in large part to the work of Eleanor Gibson), we have a first approximation as to what can be expected: verticals, horizontals, symmetries, and so forth (Gibson, 1969). The perceiving mind, even the mind of a young child, after some experience with the alphabet, grows a testing program to discriminate among the letters. We think of this program as a tree of tests.

The first theory which attempted to make this growth process and the subsequent testing process explicit was in the form of a computer program called the Elementary Perceiver and Memorizer, developed in the late 1950s by Edward Feigenbaum (1959). This program simulated the process of growing a new test structure, as well as the process of using it. Interestingly, one of the first applications of the EPAM program was to reading. Feigenbaum and Simon (1963) showed that a system capable of performing paired-associate memory tasks is capable of reading names of objects. The important requirement for this is that a minimum of three distinct encodings or representations of the stimuli in reading is necessary. The net must discriminate among aural phonemes, the sound of words, letters; another set of tests must distinguish among visually presented letters and syllables; and still a third must recognize objects in terms of their visual characteristics, shape, color and the like.

The importance of the simulation was that it forced the simulators, the theorists, to confront problems that we all too often sweep under a theoretical rug. For example, there is the problem of the natural, unschooled development

of feature-testing abilities. When a child looks at Daddy's copy of the New York Times--especially when he looks at it upside down--what tests is he growing? In psychological laboratories and in schools we manage to avoid that question. But if we tried to simulate the growth process we would not be able to avoid it. We would be forced to make our speculations explicit, and to design ways of testing them. Perhaps the most crucial issue to emerge in constructing an explicit model of an association memory is the number of levels of indirection necessary for such a structure to operate.

Although there is little research on humans, there is a growing body of animal research on the neurophysiological nature of feature detectors. Specific brain cells respond to specific kinds of visual information--horizontal lines, vertical lines, diagonal lines, and so forth. Groups of these cells, when activated, fire higher-order cells--pattern-detectors. Thus a single higher-order cell assembly may be responsible for the detection of a pattern.

The animal evidence also indicates the existence of critical periods in the development of feature detecting abilities. Clearly some kind of learning, exposure to patterns, imprinting--whatever we want to call it--must go on at a very early age.

Someday we will have detailed models of the development of human feature detectors--models which will describe neurophysiological changes in the growing brain, and specify the extremely high speed operations that we refer to as P-space tests. An important component of these models will be specification of how the P-space increases in complexity. With age and experience, the P-space grows rich and intricate. Tests develop for <u>chunks</u> or <u>patterns</u> which are as fast as those for lower-order features. We develop the ability to test syllables, spelling patterns, word roots, prefixes, and so forth. These perceptual abilities become, in some sense, <u>built in</u> neurophysiologically.

Or at least they should. There is probably a class of disorders included in that catch-all phrase dyslexia, which results from growth problems at this level. The P-space in some children does not become elaborated in normally organized ways. This may be a type of perceptual confusion analogous to astigmatism or other types of visual disorders. The point is, that for practical purposes it is a neurophysiological disorder, a brain dysfunction. Someday, when we have proper models of normal P-space functioning, we may be able to fix these disorders prosthetically, just as we can fix astigmatism by fitting glasses.

Many other so-called dyslexic disorders, however, are probably not P-space disorders, but are difficulties involving the outcome of P-space operations. When we say that a child is learning to perceive letters, we are implicitly referring not only to high speed feature detection, but also to the child's ability to associate test outcomes to some other learned information--like the name of the letter, or its sound. Those two kinds of processing--perceiving and associating--are governed by different principles. We turn now to some of the principles of association.

Recognizing Familiar Objects

In Fig. 1 a terminal node, the square box is distinguished from test nodes that appear earlier in the perceptual sequence. If graphemic stimuli can be sorted to a terminal node, an act of recognition has occurred.

At the termination of feature-testing, there is an internal name, a symbol pointing to whatever information has been associated with that graphemic stimulus. When we say a word has been recognized, we are really saying that it now

has a symbolic form which will permit it to be associated with other symbols.

It is important to distinguish between the visual recognition of graphemes and the recognition of previously learned speech sounds. A child may be able to perceive a word perfectly well visually, but not recognize it because there is nothing in his memory that the percept is pointing to. On the other hand, the child may recognize a word when he hears it, i.e. when he tests acoustic features, but may not be able to process the graphemes visually.

There has been a major controversy in reading over whether recognition must always involve auditory recoding. In our terms, the question is: "Must the pointer always be to the sound of the word?" The relationship labeled R1 in Figure 1 is the articulatory code for saying, "cat." A word sound may be the only thing a beginning reader recognizes. We will come back to this issue. For now, the point is that recognition is the termination of a perceptual testing process--a termination which exists in the form of a pointer to other previously acquired learned information. What happens after that is a semantic issue.

The Semantic Space

The semantic space is symbolized in the lower right portion of the Figure 1. There are several fundamental parts to the space, and there are a number of different ways of representing them--depending upon the notational system one chooses.

A closed area represents what we ordinarily call a concept, an addressable location in the memory. It is a node, a symbolic entity, an internal name which serves to index the properties and relations that define it. In Figure 1 the index is called KAT, so we will be able to refer to it.

The node has associated with it a set of properties--such things as color, shape, size, texture, plus additional information: functions, contextual information (where the concept is likely to be found, for example), linguistic properties, and everything else that you know about the particular concept in question. The links between the properties and the conceptual node are relations. There can be superordinate relations--a cat "isa" animal; and properties--a cat has fur. There are also related actions--a cat scratches.

As the diagram suggests, it is possible to get from any part of a semantic network to any other part. The idea of bouncing can lead you to the idea of ball which in turn can lead you to the idea of red. If all of those entities are activated by a syntactically correct program, you have the idea of a bouncing red ball.

Because it is theoretically possible to get from one part of the semantic network to any other part, what keeps the entire net from lighting up at once? Presumably, the limitation is in our short term memory capacities. We are able to use only a very small portion of our knowledge at any one time. These severe constraints have affected the way in which knowledge is gathered and stored, as well as the way in which it is later accessed. Semantic memory is organized.

What is the nature of this organization? A good deal of research suggests that the organization is categorical, and that the categories are arranged in hierarchies. Much research has also been directed toward the notion that we have schemata or frames or scripts which make it possible for us to use semantic information efficiently and selectively (Abelson, 1976; Bobrow & Norman, 1975; Rumelhart, 1975; Winograd, 1976.

For example, when we read or hear the word hit, we expect that some kind

of object--like a ball--is going to be involved. We have a schema for verb-object relations of this type, a schema which is independent of any particular verb in the class. We have schemata for picking up many kinds of semantic information that direct us to look for information. Thus, initial information is verified or disconfirmed by subsequent information. Verification of schema is an important aspect of reading comprehension. This is a burgeoning area of research shared by linguists, psychologists, and the artificial intelligentry. Most of the developmental research in the area is concerned with schemata for single words--like buy, sell, or give. We have recently completed the only study we know of on the development of semantic schemata of a more complex, sentential sort.

We were concerned with the young child's ability to activate schemata involving an agent, an action, and an object. For example, think of a baseball player at bat and then of a baseball. Does the ball "go with" the first scene? Does a hotdog go with it? Does a letter go with the scene of a postman walking down the street? Does a tricycle go with the postman scene? We used 10 different agent-action slides, and 4 different types of objects which were more or less related to each of the 10 stimulus slides. After each pair of slides the subject was asked: "Does this go with the picture you just saw?" The subject's decision time--to answer "Yes" or "No" was recorded, and the subject was then asked for an explanation.

The explanations were scored in terms of the simple process model shown in Figure 2. The levels represent 3 types of schemata that could be employed in making a decision.

Insert Figure 2 about here

A Level 1 schema includes a belief that the object--the baseball, say--was an inevitable part of the agent-action scenario. For example, as one child said: "When someone's hitting a ball, they need a ball." There is a very high frequency of association. We can think of the schema as a frame with a blank for the agent, a blank for the action, and a blank for the object. When the first two blanks are filled, a candidate for the third one is quickly detected.

But suppose, instead of seeing a baseball, the subject saw a hotdog. Does a hotdog "go with" the baseball player at bat? You might decide yes, but in order to do so, you would have had to generate some actions associated with hotdogs, and perhaps some other actions associated with the baseball player--the fact that he eats, for example. That is a more complex type of schema, which we call a Level 2 schema. If it has been activated, the subject will say something like: "Yes, the baseball player and the hotdog go together because baseball players can eat hotdogs."

A "Yes" followed by that type of explanation should have had a longer latency because you probably generated and tested the Level 1 schema first, and then generated some more ideas after you rejected the Level 1 possibility. Under the guidance of the schema, you noticed additional properties associated with particular nodes. You explored a more remote area of your semantic network.

Of course you might also reject the Level 2 possibility. We would consider that to have happened if you said something like: "Yes, the baseball player and the hotdog could go together because the player would be hungry after his game, and would then go and eat a hotdog." That kind of answer contains what we call a compatibility test: even though the action of hitting a baseball and the action of eating a hotdog could be connected through the

node of the player, those two actions are not simultaneously compatible. The man could not do both of them at the same time. Or perhaps in the same place. For whatever reason, the appearance of a compatibility test in a verbal explanation reveals the existence of a higher-order in functional rule. That type of "Yes" decision should have the longest latency of all.

So far, we have discussed only "Yes" decisions. "No" decisions should take somewhat longer than "Yes" decisions, at each level. The assumption is that a "No" decision includes some kind of transformation from positive to negative, and these take a small but measurable amount of additional time (Clark & Chase, 1972; Just & Carpenter, 1976).

The experiment was carried out using eight adults and eight 5-yr-olds. Each subject saw, in a random order, all 10 stimulus agent-action pictures, paired with each of four object pictures. That amounted to 40 slide-pairs altogether. Decision times were recorded automatically by means of a voice key. Verbal explanations were recorded on audiotape. Table 1 provides a summary of the results.

Insert Table 1 about here

To begin with, children are generally slower than the adults, by about half a second on the average. Second, when the "Yes" and "No" judgments are combined, the adults and children show about the same relative increase from Level 1 to Level 2 to Level 3 decisions. The interval from Level 1 to Level 2 is shorter for both children and adults. The general pattern is consistent with our model, and it suggests that 5-yr-olds are going through roughly the same semantic decision processes as the adults are--when the children go through any decision processes at all. To explain that last statement, look

first at the "Yes" and "No" means. For the adults, the "No" judgments--with all levels combined--are about 200 msec longer than "Yes" judgments, as is consistent with a large amount of "Yes"--"No" literature. It is an accepted fact that affirmative decisions take less time than negative decisions, if everything is properly controlled.

Among our 5-yr-olds, however (and this is actually a replication of a previous experiment using different groups of children and adults), we have a very different situation. Children take much longer to decide "Yes" than to decide "No." The effect is especially striking when we separate the levels, as shown in Figure 3.

Insert Figure 3 about here

For adults, a "No" decision always took a longer than a "Yes" decision; the effect replicates from level to level. Among the children, only the Level 1 decisions begin to look like the adult functions. Level 2 and Level 3 decisions are much slower when they are affirmative, than when they are negative. Why should this be?

We think that the "No" times do not contain the decision functions. The child was saying "No" first, and figuring how why afterwards. The "Yes" times do contain the decision functions. The child thought about why he was making a particular decision before he made it.

In terms of our model we can think of it this way: the child either decides "No" on the basis of a Level 1 schema, or he decides that he is going to say "Yes." Having decided to say "Yes," he then chooses a Level 1, Level 2, or Level 3 schema for formulating his judgment. This suggests that even though 5-yr-olds are capable of activating higher order schemata, they do not

necessarily utilize that capability in any particular decision. If they have utilized it--that is, if they have explored the semantic net, and have constructed some relatively remote hypotheses--then they are likely to view the outcomes of their labors positively. This may be something like a dissonance situation: Because I am going to so much trouble, any connection that I finally turn up must be a valid one. Whatever the reason, it is apparently easier and faster for 5-yr-olds to acknowledge semantic disconnections, than it is for them to activate schemata which will permit higher order connections. That is the first point. The second point is that having invented a higher order connection, the child respects it.

Pedagogically, the implications of such research are straightforward. We should base beginning reading materials on schemata which children find natural and easily activated. Because we do not yet have detailed models of what these natural schemata are, our best recourse is to use the child's own language. This may give rise to schemata which strike adults as unusual. Figure 4 is a language-experience chart which seems somewhat ungrammatical, as adults think of sentence rules. But the schemata represented are the ones which were natural to this particular group of children, following a particular kind of experience--they had just visited a museum. It is the research scientist's job to discover

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Insert Figure 4 about here

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and specify the nature of such schemata. If they seem unusual to us, it is because we are not yet as theoretically sophisticated as 5-yr-old children. Until we are, we should design reading materials which are based on the natural integrative structures of children. If we do not, we may be forcing beginning

readers to spend previous attentional capacity on schemata which are not natural to them, but which happen to be ones which adults prefer.

We take up the complex matter of attention in the next section.

Control Programs: A Taxonomy of Reading Tasks

We have now sketched some of the basic structures and functions which are involved in any reading task. For any type of reading, some kind of stimulus material--letter, words, or whatever--must first be discriminated, sorted through P-space structures. The outcome of the sort will then shift the processing into the semantic space, where different kinds of processing will occur. To construct a theory of any reading task, we must be able to specify a unique program of attentional control. Attention is directed by the program from one type of cognitive activity to another.

Since skilled readers can perform a variety of reading tasks, it must be the case that a control program for one type of task bears some kind of systematic relationship to control programs for other tasks. This is also implied by the fact that the programs are operating on the same P-space and the same S-space structures which are highly stable for normal individuals.

Table 2 is a taxonomy of reading tasks. The tasks are arranged along two dimensions which we believe to be key parameters: size of unit, and number of operations.

Insert Table 2 about here

Units can increase from letters, or pieces of letters, to whole passages of words. Number of operations in any given act of reading may be few, or

they may be many. Within this general framework, it is intuitively helpful to block out some familiar categories. Developmentally, we are used to thinking in terms of pre-reading levels, beginning reading, reading, and skilled reading, so those categories are marked. We are also used to thinking in terms of such tasks as reading-to-learn, or constructive reading, as compared to confirmatory types of reading. These categories are marked along the top, and will be explained in more detail as we go along.

Let us think first of what is often considered the simplest, most fundamental reading task of all: saying the name of a letter. That is our first level of sight-sound correspondence learning.

Figure 5 shows what kind of P-space and S-space operations are to be expected. The child sees the letter A, and sorts the features to a terminal node which indexes a semantic node. We have designated the semantic node as alpha.

Insert Figure 5 about here

Alpha is recognized - its internal address accessed. It indexes the image of A, assuming such an image is stored in the long term memory of the reader. It indexes information like "first letter of the alphabet" - in some memories, at least. It also indexes the sound (articulatory code) "aiee." Note that through the sound the speech-motor program for pronouncing the sound is obtained. By saying the letter aloud, the sound is recognized. As we move down the sight-sound column, the control program will operate upon larger units.

The situation becomes more complicated when the unit size goes beyond the span of immediate apprehension. Now the reader cannot take in all the necessary text elements at once. Some information must be held in a short term store,

while additional information is gathered. We can chart the control program as shown in Figure 6.

Insert Figure 6 about here

The program is described in very general terms, so you can see how broadly it may be applied. First of all, some goal must be specified. Here, we are talking about finding the name of a concept. Attention then scans a portion of the material, and holds it. The program then tests for completion of the terminal recognition unit - is there anything more to be perceived, the rest of the word, say? If the unit is not complete, the program must cycle back and pick up the rest of the information before it can move into the S-space and get the name it was after. When it finds the name, the speech-motor code must then be executed.

This cycling operation, the ability to scan and hold pieces of a recognition unit, is a developmental milestone. The ability to construct an iterative control program may be just the hurdle that every child must get across in order to get beyond primary reading. The capacity of short term memory--the holding capacity--is critical. It should not surprise us to discover, as we reported last year, that disabled readers have short term memory problems (Farnham-Diggory & Gregg, 1975).

As we were developing the taxonomy, we found hurdles of other types all the way across. For every class of reading task, as defined by our columns, there appears to be a type of new subroutine which the reader must be able to devise - in order to get into a reasonably skilled reading mode.

Verification Tasks

Let us take the next column. By Verification, we are referring to situations in which the criteria of the reading task have been set in advance. We suggest two types of verification tasks: one which involves sensory representations, like visual or sound images, and the other which comprises the existence of arbitrary semantic associations or relations. At a simple representational level, a child may be asked to connect the letter B to a picture of a ball. The goal of the control program can be set up immediately, and the efficiency of the program can be evaluated in terms of how directly the goal is achieved. The B must be perceived, and its sound accessed and held in mind. You can see how part of this new program could involve a sight-sound subroutine of the sort that was just described. The picture must also be perceived, named, and its beginning sound isolated and compared to the stored sound of the B.

As the size of the unit increases, we find such tasks as reading descriptions of objects or places. Here, the control program must get over a new type of hurdle. It must invent subroutines for handling multidimensional information.

To read about a bright red beach ball, a child must have the ability to notice several dimensions simultaneously - brightness, redness, roundness. According to Piaget (1965), this kind of control is a hallmark of the concrete operational stage. Hence, moving from a beginning to a skilled reading level on tasks of this type requires more than the simple iterative capacities required for a similar developmental step on sight-sound tasks. However, this higher-order program may include iterative subroutines.

Verification tasks do not always have a concrete representational component. That means simply that non-physical properties of a semantic unit may

be accessed. There are many other properties: ideas of lower and upper case letters, grammatical properties of words like and and the, as well as words like run. And to get from word meanings to sentence meanings, you have to be able to integrate ideas. That is another hurdle.

Since the verification programs are quite similar, the single flow diagram of Figure 7 is used to outline the processing sequences. Notice that

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Insert Figure 7 about here

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the subroutine called "get value" essentially embodies the sight-sound correspondence program shown in Figure 6, except that now a new property of the semantic unit is called for. In the case of representational verification, A2 is the physical, sensory description of the object. Alternatively, conceptual verification would test ideas established by the teacher or by the demands of the task. Verification tasks require search of the text for confirmation through words, sentences and the like.

In our view, the most important new component is the ability to compare the previously set referent with the information extracted from the text. The comparison operation can fail for two reasons: First, the multidimensional test of object properties may be beyond the developmental capabilities of the reader. Two dimensional concrete objects must be tested on property 1 and then on property 2 for both the stored image and the image derived from the reading process. Or, second, the comparison may fail from the inability to synthesize ideas extracted by iteration over the separate segments of the text.

We have labeled this hurdle cognitive synthesis, a term which refers to some earlier experiments (Farnham-Diggory, 1967). In these experiments,

children learned whole word symbols, or logographs, for familiar words. In this way, it was possible to test the integrative capacities of children who were too young to have learned the alphabetic writing system. After learning the logographs, the children were shown sets of them in simple sentences, like "jump over block." They could read the logographs perfectly. They were then asked to "do what you said." Young children, instead of jumping over the block (a block just happened to be on the floor), jumped up in the air, made a sign for "over" and pointed to the block. They acted out each symbol one at a time, instead of putting all the symbols together mentally, and then acting out their combined meaning.

That research was without a satisfactory theoretical context until recently. Now we think of synthesis as a type of simple linear schema. To get conceptual meaning out of a sentence, the reader must apply a basic schema of collecting a set of words before computing meaning. You can see this is a version of the scan-and-hold program discussed earlier.

Purely conceptual programs of this type are apparently more difficult than similar programs which contain representational cues. Rebus languages are said to be pedagogically simpler than alphabetic languages (Farnham-Diggory, 1972). However, the trick here would be to select pictorial cues which are exactly what you want semantically so that the comparison operation is direct.

We experimented with a rebus task of the following type: A child was shown, for example, the numeral 1, a swatch of red yarn, and a wooden square. In response to instructions, he read aloud "one red square." He was then shown a card containing such things as blue circles, green triangles, and red squares, and was asked to "find what you said." Young children pointed to any old square. They did not integrate the number, color, and form properties - unless they

were specifically instructed to listen to what they themselves were saying. If they listened, then they integrated all the information.

The experiment suggests that semantic integrative schemata are associated with spoken language before they are associated with written language, which is no surprise. But the experiment carries a warning for rebus pedagogy. Do the schemata elicited by pictures match those of natural language? Does a picture of a tin can elicit the same schema as the word can? Unless we can be sure of that match, or at least sure that the child is attending to his spoken schema rather than to the pictured schema, we should be wary of rebuses.

Constructive Reading

In a constructive reading task the criteria are not given--the reader must generate them as he goes along. Of course this type of reading involves verification, which is to say--programs in the rightmost columns include subroutines from columns to their left: verification subroutines, and sight-sound subroutines.

We were not able to think of a type of constructive reading task that could be carried out by the pre-reader, except, perhaps, making up meanings to go along with graphemes.

The beginning reader demonstrates constructive skills when he recognizes the difference between the word run as in the sentence I can run, and the word as used in the sentence He hit a home run. To understand either sentence, the reader must construct a meaning test, and then verify it.

To get beyond that level of simple disambiguation, the beginning reader must become able to use the semantic schemata we were describing earlier. One important characteristic of the language-experience method is that it puts

children into a constructive mode from the onset of reading instruction. The development of a language-experience control program always involves connections with semantic information the reader already has. The reader--knowing this--can generate and test his own comprehension goals

A salient application of more complex schemata occurs for many adults when they try to read, with comprehension, a recipe, or a set of directions for putting a model airplane together. A recipe tells you everything you need to know if you already know it. As you read along, you must accurately pick up cues for activating procedural subroutines. These may involve the simple diagrammatic skills referred to earlier (DIAGRAMS, MAPS) but they also involve ongoing controls for incorporating such subroutines into a more complex program. Unless you are doing that, you are not really understanding many types of technical, scientific, or mathematical writing.

In the final column, headed Remembering, we have tasks that involve reading with intent to learn. According to Flavell (1970), we should not expect that sort of reading in a beginner. Indeed, we do not find it in many adults. Reading-to-learn always involves the construction of strategies for deliberately altering the S-space. At the level of simple reading, the learner may alter only a few semantic elements. At this ultimate reading level, however, the reader takes in information which may reorganize large portions of the semantic network. For example, reading Chall's book (1967) caused many people to reorganize extensively interconnected ideas about learning to read.

Reading comprehension consists of verifying representational and conceptual elements of schemata invoked purposes of understanding new information or generated for purposes of remembering information for later use. We have described what we believe to be a plausible mechanism for the perception of the visual and auditory elements essential to the reading process. We subscribe to the

current view that semantic memory is organized along certain linguistic and episodic lines. We have emphasized the importance of studying reading in the context of specific reading tasks, presented in our taxonomy, for which detailed information processing models can be constructed. The flow charts presented in this paper are less than a first approximation to the level of detail that is required to make specific predictions about the proficiency of reading performance in reading tasks.

This concludes our highly oversimplified walk through a taxonomy of reading tasks. You are no doubt seething with alternative suggestions--and that is the point: by looking at reading tasks within the framework of a single set of theoretical principles, we can see contradictions, discrepancies, and inconsistencies. But we can also see commonalities, developmental trends, instructional hypotheses, and regions for transfer of training. We can see how basic perceptual and semantic research may relate to reading. If the research is telling us something about the nature of the P-space and the S-space, then we know it must have relevance to reading, even though reading may not have been specifically under investigation. With a broad theoretical map before us, we can all work more confidently toward a program of experimental priorities.

Figure Captions

Figure 1. Perceptual and semantic elements of the human information processing system.

Figure 2. Process model for belongingness decisions.

Figure 3. Response times for belongingness decisions.

Figure 4. Language-experience chart as an example of natural schemata.

Figure 5. Sight-sound correspondences for saying the letter "a".

Figure 6. Flow chart of control program for sight-sound correspondence task.

Figure 7. Flow chart for reading verification tasks.

Footnote

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Table 1

Response Times for Belongingness Decisions

Type of Response[a]	Children Response Time[b]	Adults Response Time	C - A Difference
Level 1	1904 (56)	1344 (44)	560
Difference (2 - 1)	218	140	
Level 2	2122 (23)	1484 (37)	638
Difference (3 - 2)	468	547	
Level 3	2590 (21)	2031 (19)	559
"No"	1891 (64)	1716 (44)	175
Difference (No - Yes)	-628	193	
"Yes"	2525 (36)	1523 (56)	997
Mean	2205 (100)	1619 (100)	586

a Level refers to the model shown in Figure 2 and "No" or "Yes" to the outcomes of the decisions.

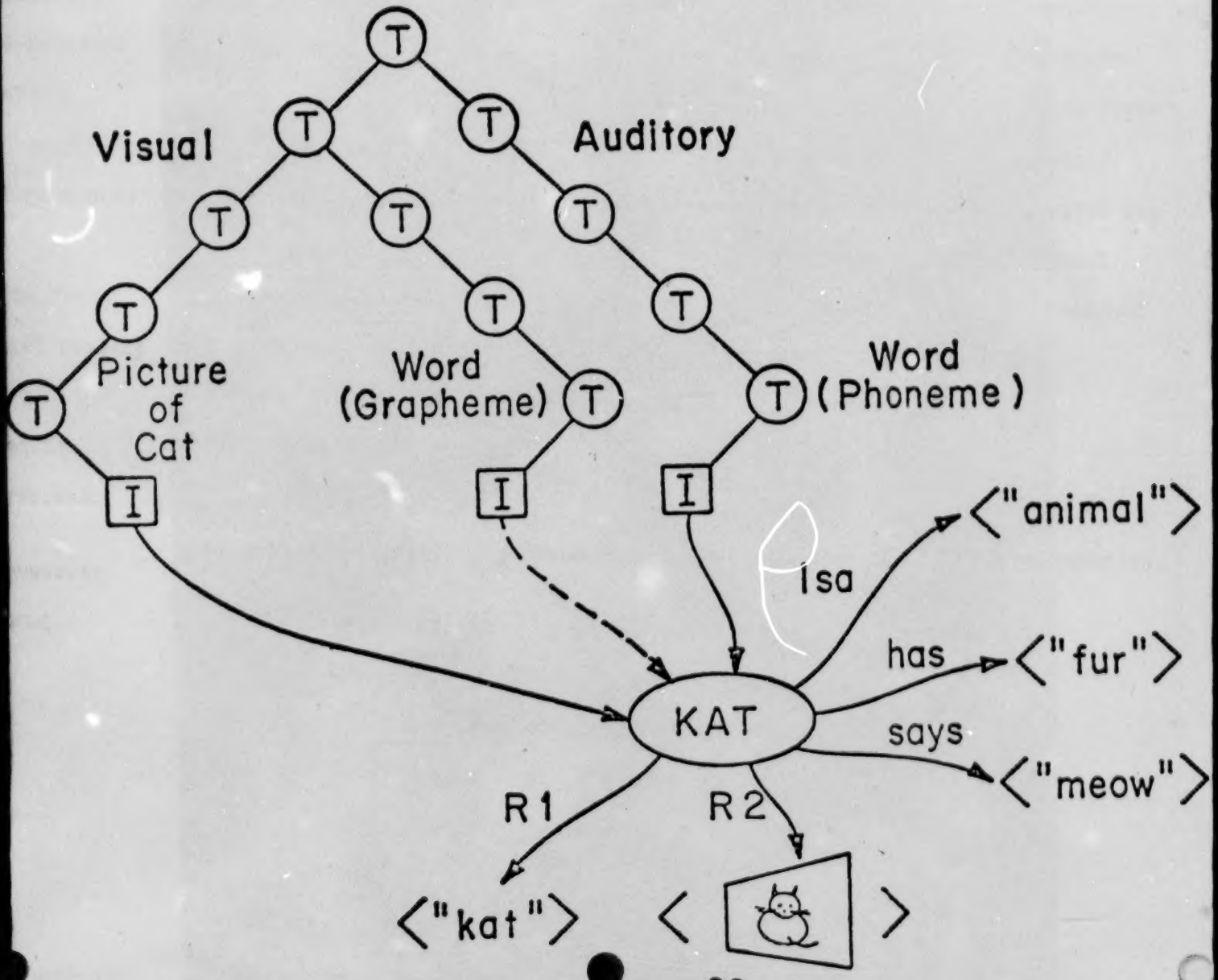
b Response times and differences in milliseconds are classified for children and adults by type of response. Per cent of total responses is shown in parenthesis for each type of decision.

Table 2

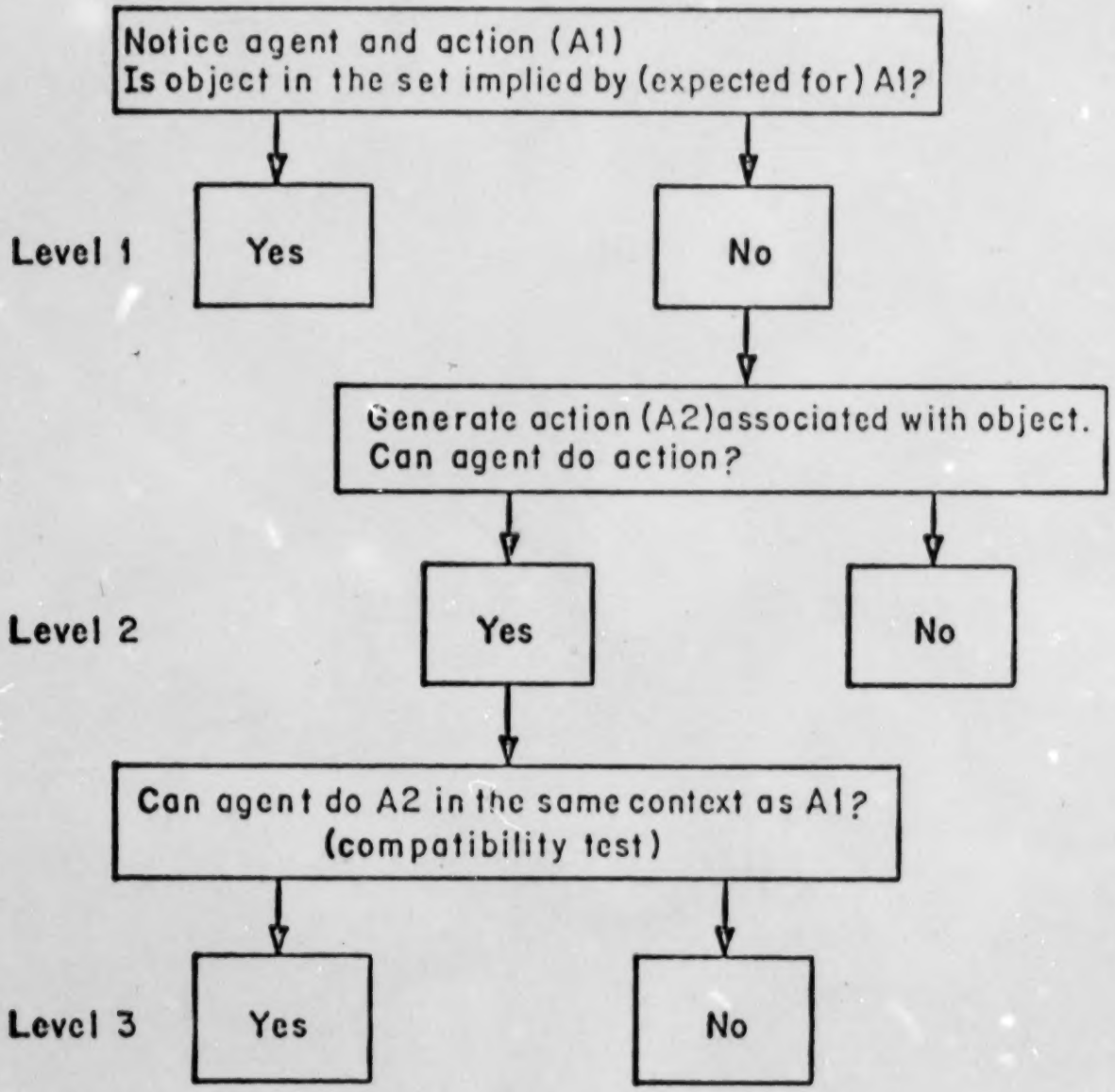
Taxonomy of Reading Tasks

Number of Operations

Sight-Sound Correspondences	Verification	-	Construction	
	Representational	Conceptual	Understanding	Remembering
Saying Letters (Pre-reader)	Letter Recognition	-	-	-
Saying Words (Beginning Reader)	Word Recognition	Word Meaning	Disambiguating Homophones	
Iteration	Integrating Concrete Operations	Cognitive Synthesis	Invoking Schemata	Generating Strategies
Reading Sentences Aloud (Reader)	Object Relations	Narrative	Following Recipes; Directions	Reading For Specific Information
Reading Passages With Feeling (Skilled Reader)	Map Reading	Logical Propositions	Logical Inferences	Semantic Reorganization


Visual
Auditory
Picture of Cat
Word (Grapheme)
Word (Phoneme)
T
I
KAT
isa
<"animal">
has
<"fur">
says
<"meow">
R1
R2
<"kat">
<
>

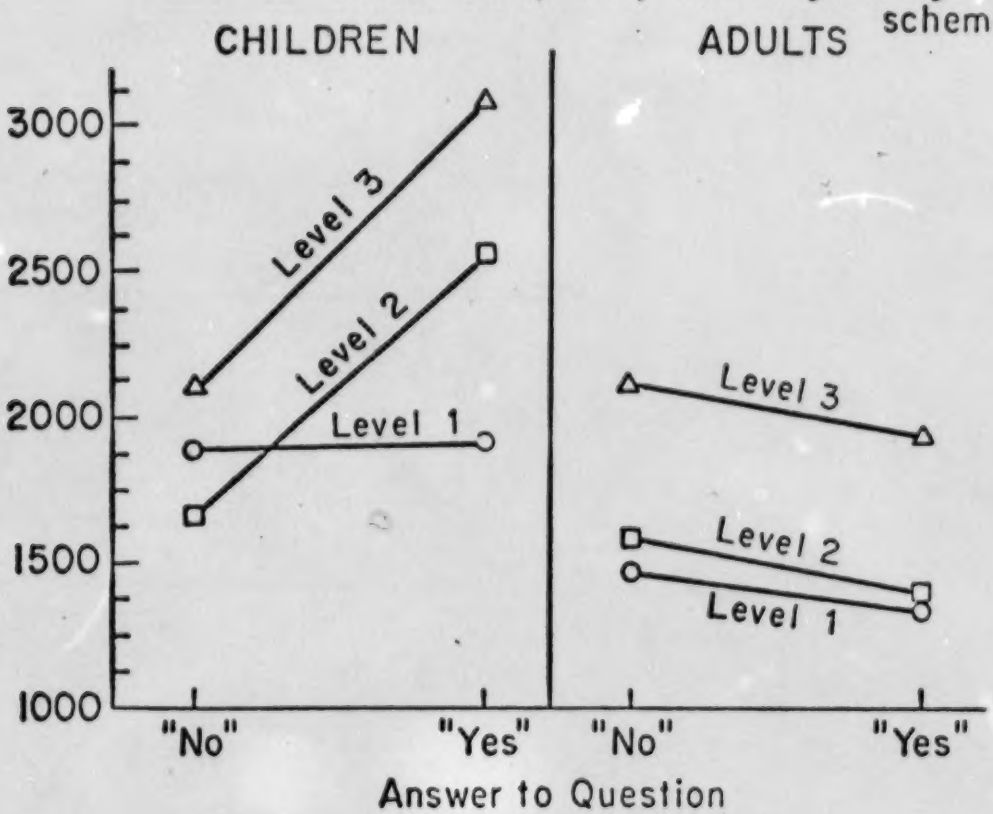
DECISION CHART FOR "BELONGINGNESS" SCHEMATA



Level 1 response: "..... because object is/is not in agent-action schema

Level 2 response: "..... because agent could/could not do action"

Level 3 response: "..... because agent could/could not do action compatibly with original agent-actic schema.....



Does (object) go with (action) ?

e.g.,	baseball	player at bat
	letter	man carrying mailbag
	tricycle	man carrying mailbag
	hot dog	player at bat

Funny Colored Pictures

Blue pictures, red pictures, zebra pictures.

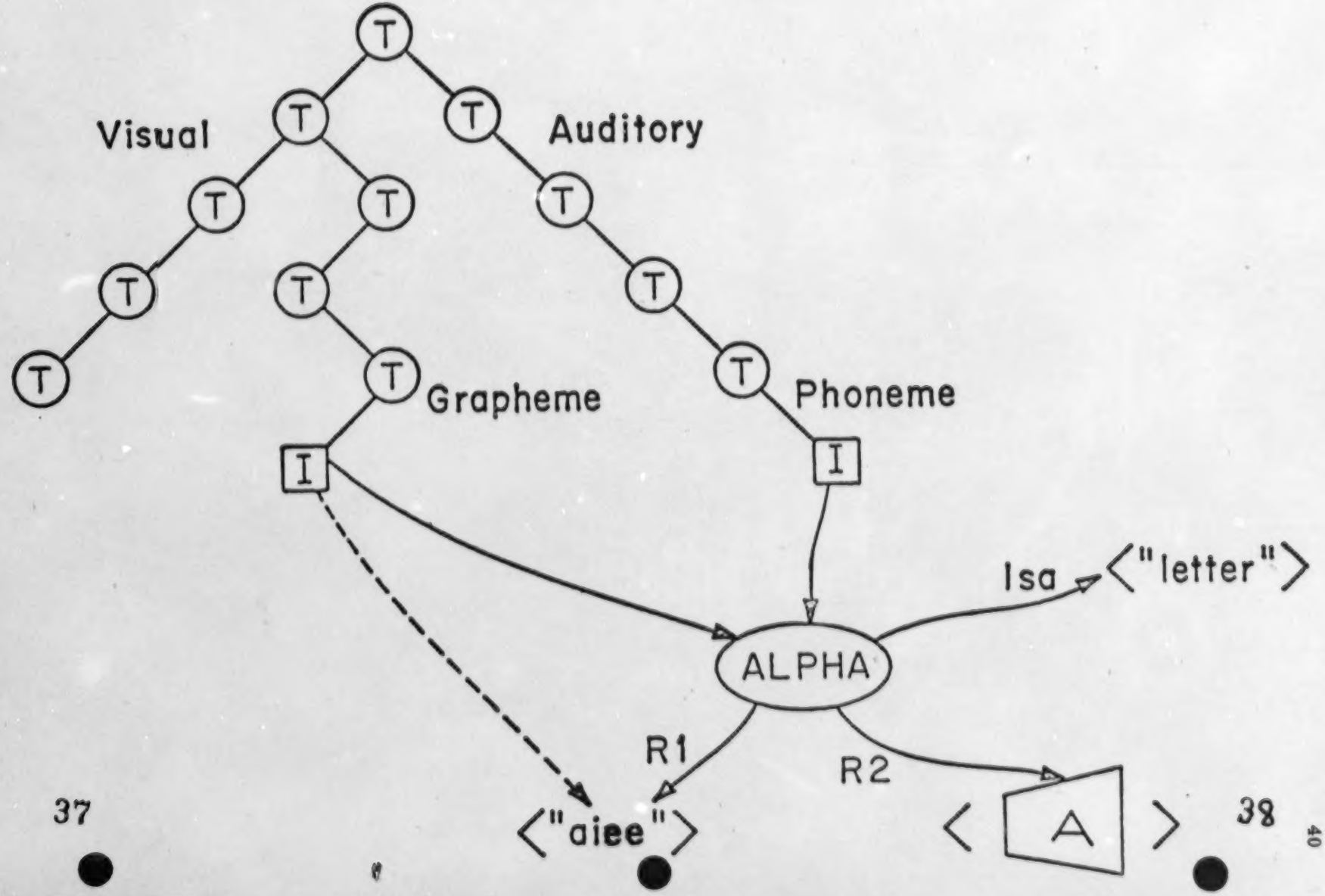
There were small pictures and big pictures.

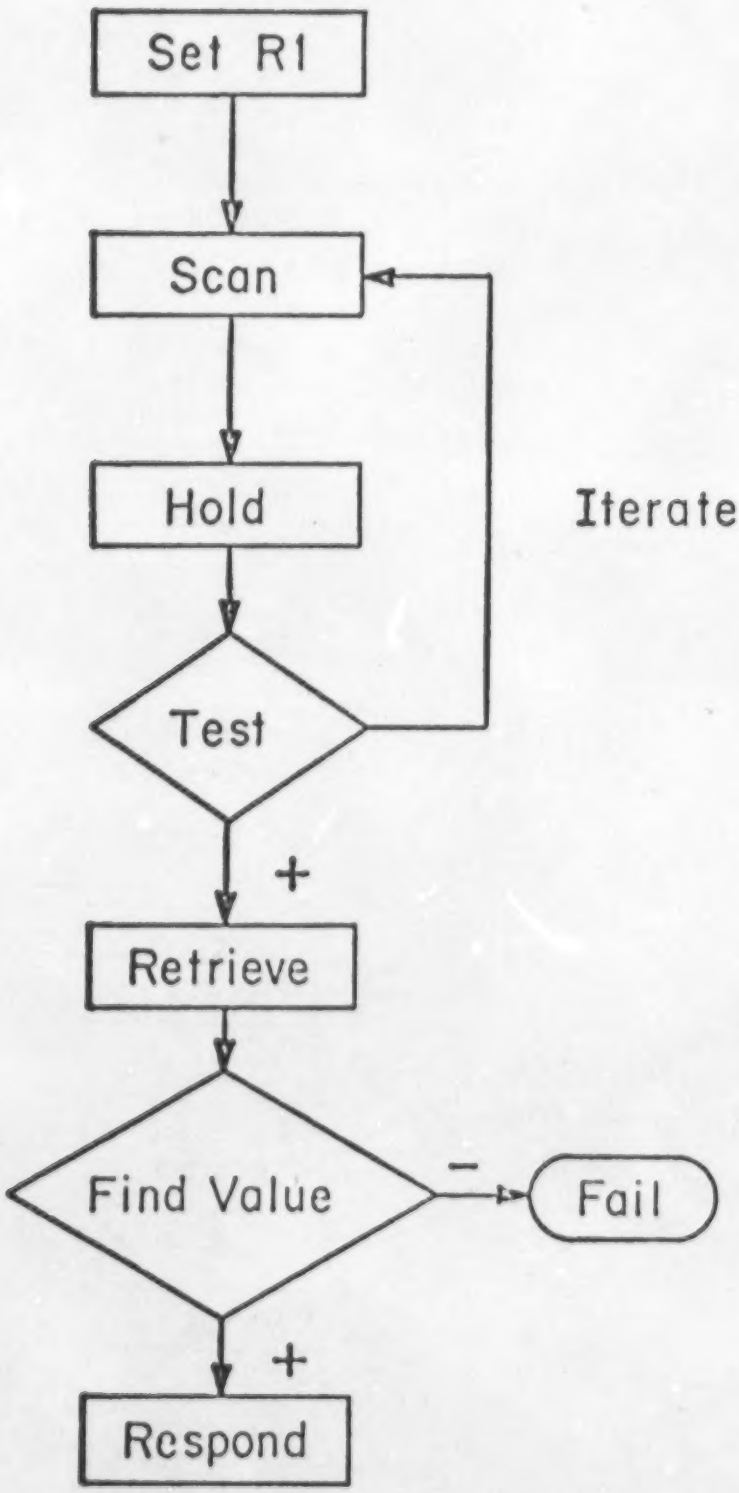
The pictures were not real.

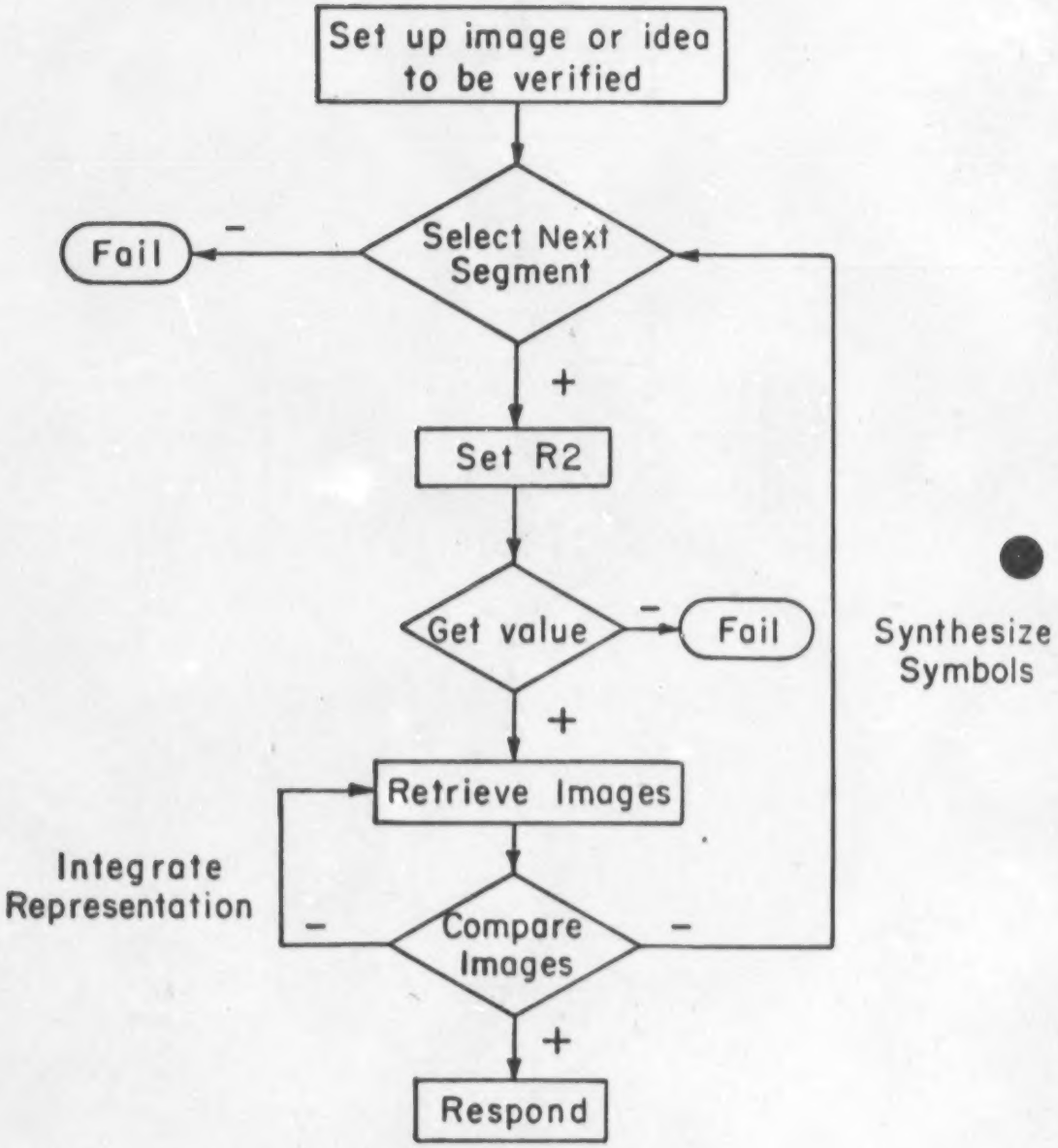
Just colors.

Many colored pictures.

A LANGUAGE-EXPERIENCE CHART CUT INTO PIECES FOR TEACHING WORD SKILLS.


Visual
Auditory
Grapheme
Phoneme
Isa
<"letter">
ALPHA
R1
R2
<"aiee">
A
37
38


Set R1
Scan
Hold
Iterate
Test
+
Retrieve
Find Value
−
Fail
+
Respond


Set up image or idea to be verified
Select Next Segment
Fail
−
+
Set R2
Get value
Fail
−
+
Retrieve Images
Compare Images
−
−
+
Respond
Synthesize Symbols
Integrate Representation

June 7--A.M.

OPEN DISCUSSION OF GREGG AND FARNHAM-DIGGORY PRESENTATION

CAZDEN: You said at the beginning of the paper, Lee, that P space versus S space is not equal to decoding versus comprehension. I wondered if you could summarize what the difference between those two contrasts are?

GREGG: I believe that decoding, as such, occurs only when there is a breakdown in the ability to perform tasks within each one of the cells of this table. In other words, what I haven't made explicit is that there is a learning process that's going on, that may be independent of the performance that one observes when someone is performing one of these tasks. When one can't perform the task, when one is faltering, then you have to fall back on some acquisition habits, and I believe that decoding as generally used in the literature is one of those helpful strategies for trying to make sense out of something that you can't do.

Thus, to the extent that the P space is not elaborated, and you don't recognize large words, then you may fall back on some cognitive strategies, like, "Can I find the stem of the word, do I know what this one means, does the prefix tell me something, does the suffix, can I separate out a letter, can I spell it letter by letter?" so that decoding is much more a collection of behaviors, to get you out of trouble when you can't just go along reading normally, carrying out the tasks as specified.

Implicit in what I am saying is that there is a difference between stages of practice, from the pre-reader to the skilled reader, but there is also a whole collection of problem-solving behaviors that aren't exhibited in this table at all. If you are at such and such a level, and have elaborated P space and S space, you can do these kinds of things. If somebody give you some materials

that you can't handle, then fall back on the learning strategies.

MacGINITIE: I wonder if "narrative reader" belongs under the "verification" category? It seems to me that understanding most narratives, even fairly simple ones, involves a lot more of constructing understandings and constructing images than we usually give it credit for. If you take a simple story and try to understand how you can logically derive the images that you form from reading that story, you find that you are going through a lot of elaborate thinking.

GREGG: This is precisely the kind of question we hoped would come from discussion, because we have had problems with that too. Let me see if I can reconstruct some of our thinking, which says, for example, that the teacher has said, the child has already learned the fairy tale or the nursery rhyme, "Jack and Jill went up the hill to fetch a pail of water." Thus the conceptual ideas already exist in the long-term memory. There already exists, in some sense, a schema, a script for "Jack and Jill went up the hill, they got the pail between them, they got the water." That whole thing is already in the long-term memory. The teacher now says, "We are going to read this story about Jack and Jill," the first reading experience up in here somewhere in Fable, and just saying "Jack and Jill" is enough to instate such a schema for the Jack and Jill story.

We don't have to think of the child trying to generate it on his own, or figuring out what is happening, all he has to do is verify some words. He now starts reading the page, following along in sequence, "'Jack and Jill,' yes I know those two, they went up the hill," and so on.

What I am suggesting is that a narrative description (already stored in long-term memory) could be verified at the level of reading skills. Understanding what's going on involves taking a few words, saying, "Oh, I see, they are talking about a couple of kids; they are going for water." If you don't know the story in advance, then you have to start putting it together, constructing the problem space, as some of our people, Hayes and Simon are suggesting with respect to adults in more complicated kinds of problems. So understanding is problem-solving.

Obviously for us to do our scientific job properly, we ought to be able to cite more literature than Jason and Clark on the stars above object relationships, the stars above the cross, and the crosses above the star. These are typical experiments, I believe, where verification of object relationships would occur. Here the child is looking at pictures displayed before him. He reads the sentence, and asks: "Does the picture go with the sentence? Does the sentence go with the picture?" This is the kind of verification we have in mind.

SUPPES: In the scheme you have on this present figure, when a child has to put a sentence together, say he is reading a sentence in order to understand its meaning, then there is much more than object relations involved. Take for example the distinction between understanding "This is a red book" and "This is a fake book." The semantic relation between "red" and "book" is very different from the semantic relation between "fake" and "book." That's just a very simple example of a semantic relation between words that has to be somewhere in the child's memory system in a very specific way. Of course it is in their auditory language, and there is nothing abut reading as such that brings out that particular semantic function in a special way. But concerning the rather detailed problem of how the parts are put together in terms of semantics, I am

not quite clear as to how you see that fitting in.

GREGG: I in fact agree with what you have just said. The complex meanings, the semantic relationships in the language, is in the child's language. The kid has to know that first; he is not going to get it from reading, necessarily, until he's at a very much more advanced stage of being able to disambiguate logical propositions, for example, and presumably only a skilled reader can do that. Obviously there are many very subtle semantic hints and cues in our language, that until our linguist friends started dredging them up for us, most of us really didn't think about. For example, "Flying planes can be dangerous." So parts of speech have to be disambiguated as well.

What I meant to exhibit by this table, is a concrete versus an abstract level of processing, where there might be visual imagery, auditory imagery, and word recognition cells. A cell that says word recognition, for example, is the one where the child might be working with a workbook and see a picture of a ball. The object is obvious and the picture elicits the child's statement, "Oh, that is a ball." The assignment is, "Pick out the word on the page that stands for that object."

And there is "ball" and "bat" and "bin" or "bag," and the child has to do word recognition in the context of a previously set concrete representation. And verify, presumably, "Oh, yes, ball, I process that one, and it gets me to the picture that I already learned."

The subtleties are great. How those are resolved, again I agree, has nothing to do with the learning to read per se.

SUPPES: Take my example of, "This is a fake book" and "This is a red book,"

there is a different relationship between the two. Would you think of understanding that by going back to the auditory representation of words, and putting that together from the experience with spoken language?

FARNHAM-DIGGORY: To begin with, one would expect that understanding the sentence, "This is a fake book," is something that a very young child isn't going to be able to do. Right?

SUPPES: No, I think six-year-olds would have that concept. I will make a wager on that one. I do not mean a two- or three-year-old, I'm talking about readers now.

FARNHAM-DIGGORY: If they are readers, then this chart simply provides a way of describing what kind of readers they are. If they can only decode, they would fit into one cell. If they can perform certain comprehension operations, then they would fit into other cells. That's all this taxonomy means.

GREGG: In order to make sense of what you have just said, we are not really talking about the verification, we are talking about a complex verification, where there is something to be disambiguated. Here is a disambiguating homophone: "He hit a home run," or "He saw the boy run home." Here is another case where there has to be some context in which the word is sorted, and the correct meaning obtained. Each of the different meanings of words that sound alike have to be analyzed and understood in different contexts.

SUPPES: Isn't there a level between word meaning and, let's say, cognitive sentences, in terms of putting the parts together, that is--

GREGG: Those are the five hurdles that we viewed as sort of the crucial developmental issues that would get us beyond word recognition and to understanding words in an episodic script-like context.

SUPPES: What I am asking for is what goes beyond word meaning, how much do you break that down, and what specifically are the theoretical ideas about the steps from word meaning to putting the parts together.

GREGG: The theoretical step, I believe, is invoking some context in which those word meanings are then matched or not matched. Remember, we spoke of an object, action, agent, instrument scenario. "The boy hit the ball."--"the baseball with the bat." So there is an agent, the action is "hit," the object is "ball," and we have got a bat. Now, notice that one of the subtleties is if you say, "The boy hit the baseball," you just know that it was with a bat, because that's the thing that goes with baseballs. He may have hit it with an old stick, because his bat was broken. Context is built up, and one of those constructive frames, or scripts, is invoked, and word meanings make sense only to the extent that they match what is known about the constraints or the limitations of words in the context. That's as good an answer as I can give.

The question is, of course, to what extent can we generate contexts, schemata, frames, that are parsimonious. Al Newell a few weeks ago at our conference on comprehension, sounded as if we had to have a schema for everything we did in the whole world. He said, "Gee, that is variable, our heads are going to be filled with all of these frames and schemata and I just don't see any future for it." Hopefully there will be some parsimony in the way that these are put together.

McCONKIE: I would really appreciate it if you take just a couple of minutes and tell us out of all that you have said, what things you feel we truly know about reading. What components of this scheme can we think of as being well established at this point, either because alternative views of how one might conceptualize this aspect of reading are illogical, you can't think of any other way that it might happen or we have very clear data that indicate that alternative positions are unlikely? And what are really the base points in this development, the touch points, with reality.

GREGG: Of course the fundamental answer is all of it is absolutely true.

McCONKIE: That's not true, because there are obviously alternative possibilities to many of the positions you have taken.

GREGG: Take the nature of discrimination learning, for one. Obviously discrimination learning occurs, it occurs rapidly, it doesn't occur holistically, obviously. Some such structure, as the discrimination network of EPAM seems reasonable as a way of modeling.

McCONKIE: Are you saying that there is at this point clear evidence that the acquisition of featural information is sequential in nature?

GREGG: I was in a laboratory the other day with a dove's brain open, with an electrode in it, and, boy, I could put horizontal and vertical lines in different places in the brain of a bird. That was pretty compelling. You can get into individual cells that are on and off, periodically.

McCONKIE: Is it clear at this point that the acquisition of these features is serial.

GREGG: No, I didn't say the acquisition as such.

McCONKIE: By acquisition, I mean when a person looks is there a sequence in which the features are encountered, that some features are encountered before others. Now, was that part of the series of tests?

GREGG: Yes.

McCONKIE: Is that well established at this point?

GREGG: Yes, I believe so. What we are talking about is a way of interpreting a great deal of information to a given set of data. There are aspects of this model of visual perception, or this aspect of visual perception and auditory perception, that are sufficient to demonstrate that visual objects, auditory objects can in fact be asserted in this way, and yield internal information.

McCONKIE: Now, my question is: Has the alternative position that features are not detected serially, but a number of them detected at once, been ruled out at this point?

FARNHAM-DIGGORY: Are you talking about parallel and serial processing?

McCONKIE: That distinction breaks down.

GREGG: Let's forget about that distinction. I have left unspecified what these tests are. No, they are not the original binary tests of EPAM; "Is it a vertical line or a horizontal line?"

Maybe at a very early stage of learning, the child may look at the letter E, and the teacher may say, "Look, it is up and down, there is a straight line there." That may be something that is problem solving, but may not necessarily be a test in this kind of structure. I believe that these tests are organizations at the neuro-physiological level, and I believe it is a tree-like, not a network, set of relationships, as we have in this other memory structure. And it happens rapidly, and it happens in a few hundred milliseconds, from 500 to 1,000.

These kinds of tests, it seems to me, are entirely sufficient for discriminating all of the words that we have ever seen, all the letters, all of the concepts, all of the auditory and visual stimuli that we will pick up in a lifetime. In just 10 levels of these, 10^{10}, figure it out. How many words are in your vocabulary, how many different scenes, images can you create by hand and eye? You know, I believe the recognition memory is entirely sufficient to recognize everything that you will pick up in a lifetime of visual discrimination learning.

McCONKIE: Now, what I gather that you are not saying is that other alternatives have been excluded.

GREGG: What are the other alternatives; that is the crucial issue, isn't it?

McCONKIE: But you are not saying at this point that other alternatives have been excluded.

FARNHAM-DIGGORY: What is an example of one?

McCONKIE: That's what I am trying to find out. Is this the chosen alternative, because this was the only alternative which we have at this point that will do it? Or are there are other alternatives, and on the basis of our present data we can say that things are being handled sequentially in terms of these tests, for instance, instead of not sequentially, or that this is indeed a tree structure.

GREGG: We are going way back to perceptions, they hit the fan.

McCONKIE: Or are we working with a model which seems to be sufficient without considering others?

GREGG: I think much of the confusion arises because we look at different stages of practice, different developments of the system and we are seeing snakes from the elephant's tail and trunk, instead of the barn door that we should be looking at.

WEDDINGTON: Isn't this predicated on the assumption that reading is occurring in the same language that one has learned to speak? What happens when you take the youngster reading a language different from the one in which he has learned to speak?

GREGG: We often speak of reading as aquiring a second language, or it could be a third language for the bilingual child who has two languages at home. Reading can be a next level up, a third language, or learning French on top of a native dialect, basic English. The reading could be a fourth language. Each of these

is an encoding, a representational form, and obviously there are very great difficulties.

Remember the slide with the dotted line versus the solid line? If the child hears one kind of sound, and looks at something, and then at home he hears another kind of sound, the reading isn't going to help at all. The pointers are going two different places in the memory. And so taking that kind of distinction into account is critical for the development of a structure of the sort that we are talking about here.

You have just stated a fundamental problem for the design of reading instruction: To make sure that the graphemic materials are pointing at the right things, the correct things, the understandable things in the child's memory, the naturalistic things.

RESNICK: Diana Natalicio's paper tomorrow will have a good deal to say about exactly that kind of relationship in the bilingual program.

Recess